

IMPACT OF COVID-19 OUTBREAK ON DISRUPTED SUPPLY CHAIN: A CRITICAL REVIEW OF CHALLENGES AND SOLUTIONS

JÁNOS JUHÁSZ¹–TAMÁS BÁNYAI²

Abstract: The outbreak of coronavirus has not only taken the lives of people and caused long-term health issues, but it has influenced the supply chain of service and production sectors. Not only the production, but also the related purchasing and distribution processes are influenced by the pandemic situation and new challenges have to be taken into consideration. To overcome these challenges, new strategies, policies, methods, algorithms, decision making tools were developed and used. Within the frame of this article, the authors analyse the available literature sources to identify the tendencies in the supply chain solutions during pandemic and to find the potential theoretical and practical solution to overcome challenges in disrupted supply chain. In the first part of the article, the descriptive analyses focus on the identification of research subject and scientific fields, while in the second part, the content analysis discusses the most important contributions of research works regarding problems and solutions in disrupted supply chain in manufacturing. The consequences of this literature review show that a wide range of new policies, strategies and methodologies were developed and applied to avoid first mile, production and last mile problems to fulfil the decreased customers' demands.

Keywords: COVID-19, disrupted supply chain, critical shortage, supply chain decision, resilience, sustainable supply chain operation, strategies during pandemic

1. INTRODUCTION

The pandemic of COVID-19 has forced the manufacturers and the logistic service sectors to be analyse and treat the disrupted supply activities and its effects belong the global supplier network. There are two main fields of the conventional system: manufacturing and services.

The pressure is on to make the renewing processes and services more and more efficient and sustainability to be fulfilling the increased uncertain demands of upset customers and understand the changeable social needs. The restrictions have been dissolved from the manufacturing and service activities suspension, which are serving out these various products.

At the same time, the huge challenges are the revenue declines, the unemployment situation and the right allocation of available human resources which are depended on the public health disaster and the economic crisis.

In this pandemic situation we can ask that question which suppliers able to apply the development of supply chain purchasing and procurement solutions in their current system configuration? The applications of reformed strategies are based on the modern technologies such as Internet of Things technologies and Industry 4.0 technologies. New opportunities are introduced to redesign resilient collaborative networks of suppliers and manufacturing, use digital twins' technologies and schedule the dynamic manpower for the operational sectors.

¹ Assistant lecturer, University of Miskolc, Institute of Logistics, Hungary
juhaszj@uni-miskolc.hu

² PhD, University of Miskolc, Institute of Logistics, Hungary
alltamas@uni-miskolc.hu

2. METHODOLOGY OF SYSTEMATIC LITERATURE REVIEW

Systematic literature review (SLR) is one of the most important academic research characteristics to be analysed in the particular research. It becomes available to apply relevant specific information for further decision making and consequences drawing to the research work. We present new aspects of systematic literature methodology belong to how to develop better guidance for summarizing the most relevant related research. It has a significant impact on the development of professional guidelines and standards to answer the specific questions of this current work. Using systematic methods have high potentials in the reduction of the potential for error in the emotion-based selection and the reproduction of the analysed steps in professional research.

The suitable SLR process has three main streams: (1) identifying the review area to specify research questions, and develop a review protocol, (2) processing review based on the primary journal of selected publications, (3) writing report of consequences findings along the extracted, analysed, and synthesized data [1].

The new aspects of the methodology are organized as follows: (1) formulate the problem, (2) develop and validate review protocol, (3) search the literature, (4) data extraction and analysis, (5) content analysis and (6) report with highlighting the consequences.

2.1. Formulate the problem

The first step is to define the area of the specific topic of this study based on the research questions. These questions help and control the entire review process of literature.

This analysis provides a right selection of literature, which is answering all pre-defined research questions in disrupted supply chain processes and services of the manufacturing based on the COVID-19 pandemic. It also mentions as narrow the literature to customize the subtopic of original area.

Concerning fellow researchers, we analyse all articles in the literature according to a pre-defined methodology - in a non-selective way about a specific research topic, which is providing broader insight into the problems of the supply chain in manufacturing based on the COVID-19 pandemic to be solved, as our current study represents [2].

2.2. Develop and validate review protocol

The review protocol reduces the issue of these researcher bias in the SLR. We develop literature selection protocol with criteria for the structured research questions:

- COVID-19 crisis and its affections on the disrupted supply chain in supply chain solutions point of view,
- Search for research gaps to evaluate and apply new aspects of the performance and the sustainability of supply chain solutions based on energy efficiency and environmental impact,
- Consequences from the pandemic caused the situation.

The studies on which the review report is based must be selected strictly according to these predefined criteria. This will ensure the reproducibility of the studies in the cross-check validation processes.

The review protocol should describe all parts of the review such as the aims of the study, specific questions of this research, criteria, search processes and data processing, and schedule.

It is important to note here, this validate protocol can also be used as an outline guidance protocol to achieve future research goals, also it can be modified and updated as necessary to improve the effectiveness and utility of the literature search.

2.3. Search the literature

To define the process of the detailed search is important for reuse:

- Mapping related literature by using scientific articles in the specified channel of online sources (Scopus, Research Gate, Google Scholar, Web of Science, and Science Direct). The search is presented using the Scopus database.
- Identify and limit studies to search for relevant literature in the research work. This is facilitated using keywords of search to narrow down the literature. We used the following keyword to search in the Scopus database: “COVID”, “supply chain” and “manufacturing”. Initially, 223 articles were identified.
- Refining results to find the relevant publications in the identified articles. The basis for refinement is the definition of inclusion and exclusion criteria for the description of the screening procedure. Defining all criteria is a crucial phase of the integrated review because there are several related articles in the field of covid caused supply processes and services in the possibility of recovering the supply chain disruptions. We applied the presented methodology to this field and search. Inclusion and exclusion criteria contain the following: the search list was reduced to 137 articles (1) selecting journal (2) articles only and (3) relevant subjects’ area of our research. Then used the exclusion criteria for excluding the articles, which (4) direction did not find any interest and cannot be addressed the pandemic caused the situation in supply chain solutions point of view. After this reduction, we got 126 articles. Also, (5) limit the publication date to the period of the research eligibility period. We also consider publications that have been (6) finally published and are (7) written in a foreign language that is relevant to the discipline. Finally, we (8) added relevant articles selected through a separate search in 2010 about supply chains.

2.4. Data extraction and analysis

We review and categorize specific information compared to the research questions in the full text of publications. The final list for classification and evaluation from the point of view of scientific results includes 127 articles.

2.5. Descriptive analysis

After the data extraction and analysis processes, we organize the data according to the review selection. Then, we make several custom charts, tables, and textual descriptions of the reviewed literature characteristics.

2.6. Content analysis

Based on the relevant information we make a descriptive analysis in the next section. We represent the main pieces of knowledge of this research to summarize the important

scientific results. This will help us to achieve the goals of the article and develop new results for theoretical and practical use.

2.7. Report, consequences

Once the analyses have been carried out, the results of the tests are summarised. If the analysed studies do not contain quantitative or qualitative data a narrative summary is also recommended. Based on the literature review we can prove the supply chain' consequences of the pandemic caused the situation.

3. DESCRIPTIVE ANALYSIS

The distribution of the articles from subject area point of view is shown in Figure 1. The engineering subject area is in the focus, but the importance of financial aspects is also highlighted by the proportion of business, management and finance.

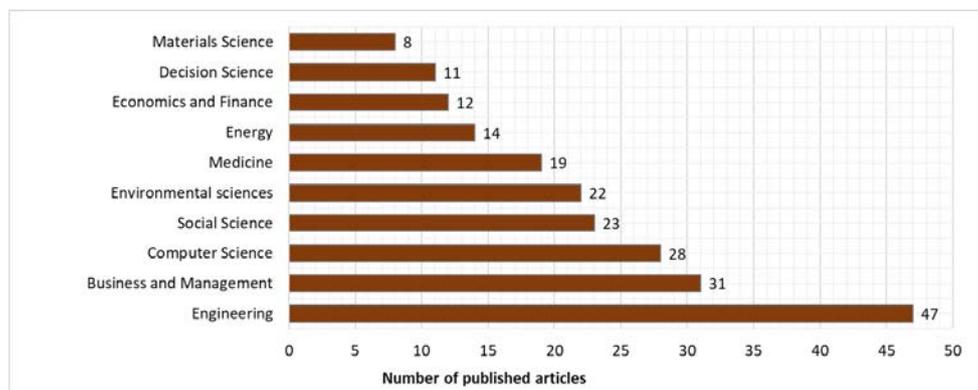


Figure 1. Distribution of published articles from subject area point of view based on the search in Scopus

The complexity of supply chain solutions led to complex models and their solutions are based on robust optimization methods, including heuristics and metaheuristics, represented by the subject area computer sciences. The pandemic has great impact both on the performance and the sustainability of supply chain solutions, where energy efficiency and environmental impact must be taken into consideration. The operation of disrupted supply chain requires complex decision making solutions. The distribution of keywords (see Figure 2) used in the articles shows the same tendencies.

As the distributions of articles by the nationality of authors shows (Figure 3), the pandemic has caused not only local problems, the disruption of supply chain is a global problem of value chain.

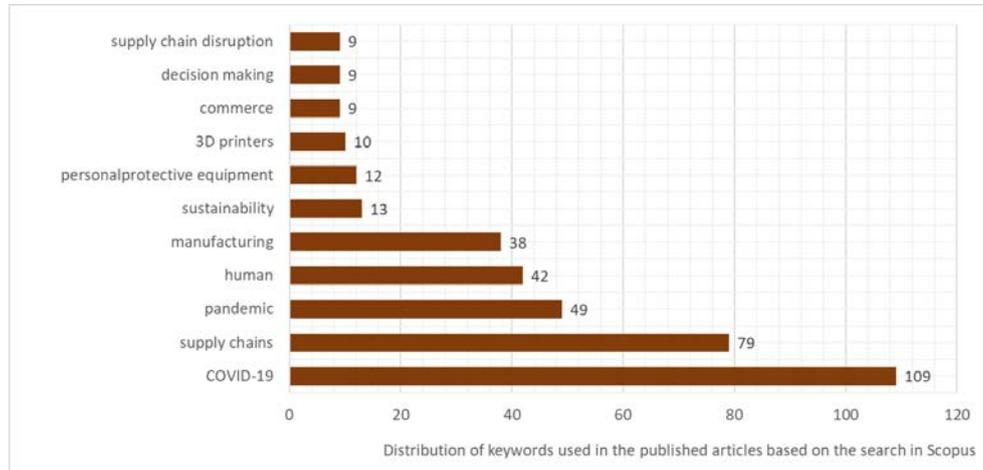


Figure 2. Distribution of keywords in the published articles based on the search in Scopus

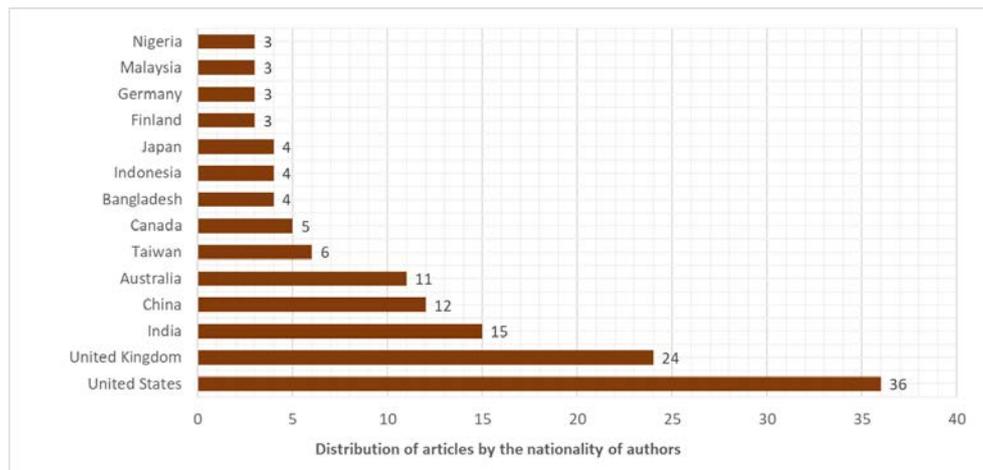


Figure 3. Distribution of articles by the nationality of authors based on the search in Scopus

4. CONTENT ANALYSIS

The challenges and solutions for addressing critical shortage of supply chain for personal and protective equipment (PPE) arising from Coronavirus disease (COVID19) pandemic represents a special research area. As a case study from the Republic of Ireland shows, the reprocessing of PPE is an important research area from closed loop economy point of view, because the shortage in supply chain of critical one-time-use PPE was a critical problem in the middle of COVID19, and a sustainable, efficient and available supply chain of PPE can support the vital healthcare provision and will help reduce mortality [3].

The disrupted supply chain influences our everyday life and has a great impact on the whole economy. In the field of manufacturing, due to strict, and dynamically changing lockdown, the manufacturing and related logistics operation are permanently suspended,

and this fact leads to the disruption of the whole supply chain including purchasing, production and distribution processes. This supply chain disruption is an especially sensitive area regarding food supply chain. Resilient and responsive food supply chain solutions can improve the reliability of manufacturing and logistics resources, while decision support methodologies using discrete event simulation can optimize the routing and scheduling operations for first mile and last mile operations [4].

The disruption of the global supply chain led to the rethinking of the global economic growth. The linear economy system including purchasing, production and distribution processes must be transformed into a recalibrated and sustainable circular economy, where not only the main stream of the material flow, but also the inverse and reverse processes play an important role in the design and operation processes [5]. These aspects are especially important in the global distribution and allocation process of vaccines, where a worldwide cooperation and collaboration was required to fulfil customers' demand [6].

The optimization of maintenance operations is a core problem in the recent global pandemic, because disrupted technological and logistics resources have a great impact on the performance of the value chain including procurement, production and distribution. New maintenance and recovery strategies can supply the increase of the availability of technological and logistics resources, which can avoid the collapse of the value chain and the fulfilment of customers' demands [7, 8]. As research studies show, manufacturing and service companies are not having proper strategies to deal the disruption in production and logistics, therefore it is unavoidable to analyse the main tendencies, especially in the field of the biggest companies. The analysis of twitter data from NADSAQ 100 firms shows, that these firms are facing challenges in terms of demand-supply mismatch, technology, design and operation of resilient supply chain solutions [9]. The automotive and airline industry represent special sectors of economy, where complex supply chain solutions are required to avoid the disruption of the value chain. The impact of COVID19 on the automotive and airline supply chain requires both short term and long term response strategies including the following main actions to be performed: transform the global supply sources into local supply sources to increase the reliability of supply; application of Industry 4.0 technologies; real time data collection from the physical processes of the supply chain makes it possible to react real time to the special situations [10, 11].

The disrupted supply chain influences not only the profit of the manufacturing and service companies but also it has a great impact on the future of the workers becoming jobless, and this is a core problem regarding social sustainability [12]. COVID19, Brexit or USA imposing tariffs have a great impact on the future design and operation of global and local supply chain. The future changes will have technological, social, financial and logistics implications [13, 14]. The supply failures caused by COVID19 influenced the material supply of manufacturers. This disrupted material supply led to capacity problems in production, and these problems appeared exponentially in the case of manufacturers producing products with substantially increased demand (toilet paper, personal and protective equipment, hand sanitizer). Researches show, that information and resource sharing from all participant in the value chain have a significant positive impact on the service level [15].

The evaluation of the impact of COVID19 is a revolutionary way to avoid future disruptions in the economy, because the vulnerability of a sub-process in the value chain can cascade through the global supply chain and it will be transformed from firm level to national or global level. New mathematical models make it possible to analyse and evaluate

disruption situations in the global value chain to identify the most critical segments of the production and service era [16]. Industry 4.0 technologies can be used to improve the availability, efficiency, reliability and transparency of the global supply chain processes. Additive manufacturing, as one of the most important manufacturing related Industry 4.0 technology offers new solutions to avoid problems caused by disrupted purchasing and procurement processes in the global supply chain [17-19]. The availability of 3D printing technologies and open source CAD design show the significance design tools of the additive manufacturing (AM) and digital supply chain for handling emergency situations and in the post-COVID era [20]. The possible of manufacture locally is opened a new industrial way to procedure some of the critical items like hand sanitizer holders, face shields, face masks ventilators and oxygen valves and other medical equipment [21].

The problems caused by disrupted supply chain can be solved in many ways. One interesting proposal focuses on the alternative supply chains, where the simplified product design can make available new suppliers. This strategy was tested in the case of products with substantially increased demand (personal and protective equipment). The simplified design influences not only the set of required and available suppliers, but also the required technological, human and logistics resources [22]. The global shortages in goods are caused by disrupted supply chain, lack of transparency, availability and resilience and the disruptions in just-in-time manufacturing. Researches shows, that these problems can be solved or their impact can be decreased by diversification and increasing safety stock in the global supply chain [23]. The cooperative supply chain solutions and the collaborative manufacturing operations can also decrease the vulnerability of value chains. The most important proposals are the following regarding collaborative manufacturing: resilient collaborative supplier networks and manufacturing operations, digital twin based real time maintenance and real time failure data and status information analysis, dynamic reconfiguration of technological resources [24].

Not only the technology and logistics, but also IT solutions can support the fight against pandemic situation. The 5G technology linked to Industry 4.0 technologies represents a powerful solution in telemedicine, education, home office, tracing and identification and e-government [25]. The effects of COVID-19 outbreak cause the companies to be identifying and recovering the supply chain disruptions along the whole material flows of manufacturing technology and logistic service. The market' participants are encouraged to give the direct response about the pandemic and reduce its effects in parallel by cooperation with government, universities and other corporations to quickly development of various products [26]. The implications of management tools are also provided to take right decisions to overcome these obstacles and enhance the resilience of the supply chain supply chain based on the fuzzy analytical hierarchy process [27] and the flexible business strategies [28].

The manufacturing industries have increased their capacities to serve out the unsatisfied demand and its fluctuation enlargement by understanding the aftershock of COVID-19 [29]. It also makes it possible to develop more robust supply chain by accounting rhetoric and technologies facilitate neoliberal globalisation [30].

Several new and innovate methodological solutions are required to renew and control the impacts of the diverse supply chain' strategy, which are needed more attention. The sector of SMEs wholesale and retail business sector upgraded their services to online by short-term pressures [31]. The AM Community collect systematically the major additively manufactured items during the pandemic and its challenges of innovative applications [32].

The aspects of innovation have opened a new technological industry to understand to use the local possibilities for procedure substantial goods such as rapid manufacturing of the medical products [33] by using digital data. The grey-based digraph-matrix measures and classify the impacts of the supply chain, especially in the readymade garment (RMG) supply to the restructure the supply chain [34].

There are also highly focused areas belong the supply strategies such as the pharmaceutical supply chain' products of the fundamental medical delivery system to requires serve constant medicines, diagnostic tools and vaccines for smooth functioning, which are already extended to the wealthy economies [35, 36]. The large-scale additive manufacturing (LSAM) able to increase the production volume belong the major thermoplastic components of the face shield [37]. This has significantly reduced the production time of each component along with the use of human resources. The intelligent manufacturing (IM) systems create a safe workplace by using the automated manufacturing assets which are monitored and controlled by the intelligent frameworks and decision-making algorithms [38].

The studies also summarize the potential threats of pandemic and propose corresponding countermeasures of further pandemic from the raw material to the sector that control almost the total food supply chain and market [39]. Initial data can provide valuable information on responses, protocols, precautions and knowledge sharing [40-41]. These impacts of the supply chain are hit up to make new standard, procedure for the operation and recovery the collaboration among each supply tiers. These processes help to mitigate the supply crises and fulfil the renewed various customer needs generated by the corona virus [42]. By collating the best-practice framework try to fix the barriers and enablers of manufacturing resilience, especially with regards to supply chain actors in response to a pandemic [43]. These aspects contain specific knowledge for next generation. The main research topics are summarised in Table I.

Table I.

Approaches and potential research directions based on the search in Scopus

Approach	Research
Purchasing	sustainable supplier selection [86], order forecast for production [89]
Production	energy consumption-based maintenance in production [8], manufacturing resilience in automotive and airline industry [10], 3D printing [17-21, 26, 32, 37, 47, 49, 104, 113, 119], collaborative intelligent manufacturing[24], intelligent manufacturing systems [38], local industrial strategies in manufacturing[41], barriers and enablers in manufacturing [43], early implications in manufacturing [51], rapid retooling in hybrid manufacturing[68], MPPE manufacturing[76], annual order forecast for production [89], peer-to-peer production [91], manufacturing of reusable half-face respirator [100], lean production [101], green manufacturing [108], sustainability in manufacturing [112], leveraging flexible manufacturing [117], resilient manufacturing [118]
Distribution	food supply chain disruptions [4], impact of additive manufacturing on distribution and global supply chain [17], alternative supply chains [22], shortcomings of current supply chain operations [23], countermeasures [29], early implications [51], fragility of a multilayer network [55], ultra-cold supply chain [63], performance apparel [79], last-mile services [83], supply chain disruption [99]
Recovery	circular economy strategies [5], recovery plan [7], supply chain recovery [52]
Global aspects	critical shortage in supply chains [3], delivery strategies [6], supply chain decisions [9], global supply chains [11], evolutionary design of supply chains [13], early impact [14], economic impact and ripple effects [16], flexible business strategies [28], neoliberal globalisation [30], impact of crisis on SMEs [31], management strategies [34], medical

	product supply chain [35], place connecting strategies [48], disruption risk analysis[50], uncertain environment [53], shortage reduction in resilient supply chain [58], alliance management [61], global supply chain constraints [64], supply chain decentralisation [66], resilient supply chain [88], global contraction in sales logistics [90], decision reshoring [94], shifting industrial landscape[96], high frequency shipping data [97], supply chain integration an information quality [106], balanced sourcing strategies [109], local manufacturing in integrated supply chains [116]
Product design	additive manufacturing [17-21, 26, 32, 37, 49, 119], reusable face shield [36], dissolvable microneedle patches [62], time-temperature indicator [63]
Social aspects	socially sustainable supply chain [12, 34, 72], humanitarian logistics [42], apparel workers [46], social capital [54], long-term economic security [57], worker protection [78], social entrepreneurs in times of adversity [105], foreign dependence of generic drugs [111]
Industry 4.0	digital twin in maintenance [8], 5G technologies [25], emerging technologies [33], impact of industry 4.0 on the improvement of supply chain resilience [71], open online marketplace [80], internet-enabled manufacturing strategies [84], additive manufacturing cluster [104], digital supply chain management [114], real-time IoT scheduling in healthcare 4.0 [121]
Optimization	digital twin-enabled maintenance optimization in manufacturing [8], agent-based model [52], uncertain environment [53], artificial intelligence power supply chain analytics [61], modelling framework for strategies [67], optimization of agricultural problems [77], hybrid DEMATEL-TOPSIS-possibilistic multi-objective optimization [85], into simulation-based decision support [87], fuzzy AHP [98], disruption risk prediction [103]
Case studies	automotive and airline industry [10], Turkish economy [14], toilet paper [15], medical face shields [22], Indian manufacturing [27], medical products in India [35], beverages manufacturing [40], humanitarian logistics [42], readymade garment [44], pharmaceutical industry [45], built environment [56], drug supply shortages in Nigeria [59], food industry in China and India [65], SMEs cooperation in Jordanian [69], Malaysia in the global supply chain [82], spinning mesh disc reactor [92], changing geographies [95], micro enterprises in Ethiopia [107], health supply chain [110], book manufacturing [115], chemical industry [122], domestic enterprises in Vietnam[123]
Sustainability	socially sustainable supply chain in clothing industry [12], economic and social sustainability [34], sustainable development goals [60], social sustainability [72], sustainable production management [73], supply chain agility and sustainability [74], supply chain integration and sustainability [75], environmentally sustainable manufacturing [81], vertically integrated sectors [93], green manufacturing [108], sustainable and resilient manufacturing [118]
Safety	regulatory and safety considerations [36], food safety and security [39, 70, 102], health care worker protection [78]

5. CONSEQUENCES OF THE REVIEW

The above mentioned literature review lead to the following consequences from pandemic caused situation in supply chain solutions point of view:

- COVID-19 has a great impact on both the short-term and the long-term performance of supply chain influencing the performance of global value chain. The adoption of short-term and long-term supply chain strategies makes it possible to overcome challenges caused by the pandemic situation and fulfil the dynamically changing, increased customers' demands.
- The application of Internet of Things technologies (or Industry 4.0 technologies) resulted, that the conventional systems both in the field of manufacturing and services can be transformed into cyber-physical systems and the potentials in real-time decision making can support the operation of disrupted supply chain.
- The purchasing and procurement strategies were in many fields of the industry changed. One of the most typical changes is to give priority to local suppliers instead

of global supplier network. This geographical reconfiguration of supplier networks can cause the mitigation of risk.

- The challenges can be recognised not only in the field of economical but also in the field of social sustainability, especially caused by the increased prices and increased unemployment. The production and service operations are suffering from both unemployment and reduced available manpower at the same time.
- The end of this pandemic situation is not predictable, therefore long-term strategies must be found and applied to avoid the expended negative impact of disruption in supply chain solutions.
- The disrupted global supply chain has influenced not only the last mile services, but it has also a great impact on manufacturing capacities, especially in the case of substantial increased demands (toilet paper, hand sanitizer, personal and protective equipment, spare parts and components of medical equipment).
- The business models must be reworked and the priorities of business strategies can be also changed, especially from humanitarian and social point of view.
- The fulfilment of customers' demands is limited by shortages of goods, which is especially critical in the case of emergency supplies, therefore a global, international cooperation is required.

6. CONCLUSIONS

The COVID-19 pandemic has resulted global and local supply chain problems. The solution directions of problems caused by the pandemic situation are based on a wide range of new aspects: technological solutions including Industry 4.0 technologies; new business models; new product design to make more flexible and transparent supply chain; new global resource allocation; new first mile and last mile solutions; more flexible logistics services. As the above-described descriptive and content analysis shows, the know-how gained during the pandemic can also be applied to the post-pandemic period, as much more robust supply chains can be established by generalising and subsequently applying the experience gained in the past period of the pandemic. One potential research direction is the analysis of the potential generalisation directions to answer the question: how we can leverage the knowledge gained during a pandemic?

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